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Effect of Feeding Various Hay-Concentrate Rations on the Production and Composition of Milk

K. C. Mathew

University of Tennessee - Knoxville

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I am submitting herewith a thesis written by K. C. Mathew entitled "Effect of Feeding Various Hay-Concentrate Rations on the Production and Composition of Milk." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Louis J. Boyd, Major Professor

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Eric W. Swanson, Rufus W. Beamer, C. C. Chamberlan, R. H. Lusk

Accepted for the Council:

Dixie L. Thompson

Vice Provost and Dean of the Graduate School

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August 14, 1961

To the Graduate Council:

I am submitting herewith a thesis written by K. C. Mathew entitled "Effect of Feeding Various Hay-Concentrate Rations on the Production and Composition of Milk." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for degree of Master of Science, with a major in Dairying.

Louis J. Boyd
Major Professor

We have read this thesis
and recommend its acceptance:

Ezra W. Swanson
Robert W. Deamer
W. C. Chamberlain
H. H. Lush

Accepted for the Council:

H. E. Spivey
Dean of the Graduate School

EFFECT OF FEEDING VARIOUS HAY-CONCENTRATE RATIONS
ON THE PRODUCTION AND COMPOSITION OF MILK

A Thesis
Submitted to
the Graduate Council
of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
K. C. Mathew
August 1961

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CHAPTER I

INTRODUCTION

The composition of cow's milk and the variations to which it is subjected are questions of great importance. This is true both from the standpoint of physiology and from the standpoint of human nutrition. For these reasons the composition of milk has been subjected to careful investigation for a long time.

The milk of all cows contain the same constituents, namely water, fat, protein, lactose, minerals and vitamins. But the proportion of these constituents vary to a considerable extent. There are two fundamental causes of variation in the composition of milk, the genetic or inherited and the environmental. It is not easy to separate the two factors. Some of the environmental factors which may be classed under management and nutrition may be said to be under the control of the dairyman while others are the result of changes in the internal condition of the animal and may be classed as physiological factors.

Of the various constituents of milk, considerable attention has been paid to the variation in the fat content. This may have been due to the fact that milk fat has been commercially the most valuable single constituent of milk. Further, comparatively easy and accurate methods of estimation of fat may have contributed to its greater attention.

However, recently much emphasis has been placed upon the solids-not-fat (SNF) content of milk. Today the public is more fat conscious and counts calories to avoid a high fat intake. The consuming public is rapidly losing interest in milk fat. The per capita consumption of cream has decreased by 30 per cent in the last fifteen years (17). Without exception, the increases in consumption of dairy products during recent years have been confined to fresh whole milk with low fat content, low fat cheese especially cottage cheese, skim milk in chocolate drinks and non-fat dry milk. The present day consumer is more interested in the caloric value of the SNF constituents of milk rather than the fat content. The calorific value of non-fatty solids in a given weight of average milk is 15 per cent greater than the calorific value of fat (9).

Milk remains a vital component of diet not only in this country but in many other countries of the world. The protein content gives milk its greatest nutritional importance, since no substitute for protein has yet been found. As such, there should be more emphasis on the protein and SNF content of milk. The object of the present experiment was to study the effect of three different rations, normal, high-grain (with limited amount of hay) and hay alone on the milk production and the composition of milk, especially its protein and SNF content.

CHAPTER II

REVIEW OF LITERATURE

The proportion of roughages and concentrates in the ration of dairy cows is a matter receiving much attention at present. This has been mainly from the nutritive and economic standpoint but also from its effect on the composition of milk. The need for roughage in the ration to prevent physiological and digestive disturbances has been reported (30). The relatively high cost of concentrates as compared to roughages makes it imperative to examine the roughage-concentrate ratio for the purpose of economic milk production. Finally, the effect of such a ration on the composition and nutritional quality of milk needs to be considered. An attempt has been made in this paper to review some of the recent findings on the effect of feeding different proportions of roughages and concentrates upon milk production and composition.

Effect of different roughage to concentrate ratios on milk production

The effect of feeding different ratios of roughages to concentrates upon milk production and digestibility of the rations was studied by Putnam and Loosli (29). In a randomized block design, rations containing 80, 60, and 40 per cent dry matter from roughage and the balance from

concentrates were fed to 12 animals for an experimental period of 112 days. It was observed that as the proportion of concentrates in the ration became larger, the apparent digestibility coefficients of mixed rations increased for dry matter, crude protein, ether extract and nitrogen-free-extract (NFE). Total digestible nutrients (TDN) and dry matter intakes also increased. The apparent digestibility of crude fiber decreased as the proportion of the concentrates increased. No significant difference in the average amounts of milk produced by the animals consuming the different rations was noted.

Elliot and Loosli (11) studied the effect of the dietary ratio of hay to concentrates on milk production. Twelve Holstein cows were grouped in trios and were assigned to a randomized complete block design with three treatments. The treatments consisted of rations which supplied 60, 40, or 20 per cent of the estimated net energy (ENE) intake in the form of hay and the rest as concentrates. Each cow was offered sufficient ENE to support maintenance and the daily production of 45 pounds of 4 per cent fat-corrected milk (FCM). The duration of the experiment was 22 weeks; 4 weeks preliminary period, 2 weeks adjustment period, 14 weeks experimental period and 2 weeks post experimental period. During the experimental period the average daily production of 4 per cent FCM of the cows fed on rations which supplied

60, 40, and 20 per cent of the net energy intake in the form of hay was 44.3, 46.0, and 45.8 pounds, respectively.

Bloom et al. (7) divided 36 Holstein cows into high, medium and low producing groups which were fed hay and concentrates in four ratios on energy basis: 75:25, 55:45, 35:65, and 15:85 for 182 days. For each cow the total feed energy requirements for production were pre-determined and partitioned into decreasing weekly quantities. Feeding was based on net energy recommendation for maintenance and production. The data collected from all the groups indicated that the milk production closely followed the estimated net energy inputs of feed above maintenance requirements. The depressed milk production and feed input of the cows at the 75:25 (hay:concentrate) ratio indicated the inability of the cows to consume the required energy largely in the form of hay. The 9 cows fed the highest concentrate ration consistently produced more milk than the cows fed 55:45 and 35:65 (hay:concentrate) ratios. However, the total energy inputs above maintenance for the 3 groups of 9 cows each at the 55:45, 35:65, and 15:85 ratios were respectively 20,808, 21,280, and 21,874 therms. The difference in the estimated net energy available for milk production at the 3 feeding levels was much greater than the corresponding differences in FCM production, which indicated that the inherent producing ability of the animals exerted a greater influence upon production than the intensity of feeding.

Smith et al. (37) studied the effect on milk production of feeding alfalfa hay with and without concentrates. Six cows were fed alfalfa hay alone for 28 days, followed by two periods of 28 days each when concentrates replaced 5 or 10 pounds of alfalfa hay, and again by a 28 day period in which alfalfa hay alone was fed. This arrangement of feeding was continued throughout the lactation period. The digestible protein intakes were kept at the same level as when alfalfa hay alone was fed, by mixing the concentrates with starch or sugar. It was observed that the milk production was maintained at a higher level when part of the alfalfa hay was replaced by concentrates. It was assumed that the total digestible nutrient system of feed evaluation considerably overrates the production value of alfalfa hay when fed in large amounts to good dairy cows. The rations did not seem to have any consistent effect on the percentage of fat in milk.

Sherwood and Dean (35) fed one group of cows alfalfa hay and another alfalfa hay and concentrates for four lactation periods. The hay fed group produced on an average 5,875 pounds of milk (mature equivalent (ME) 4 per cent FCM) while the other produced 7,181 pounds of milk. The production on hay alone was 81.8 per cent of the group fed hay plus grain. The ME butterfat production was 266.4 pounds for the hay group and 322.2 pounds for the hay-concentrate

group. No significant difference was observed between groups with regard to the SNF content.

Lindsey and Archibald (22) reported the results of an investigation for three and one-half years on the relative merits of two systems of feeding dairy cows. One of these systems involved the feeding of a relatively large amount of roughage and a small amount of grain; the other involved the feeding of a relatively small amount of roughage and a large amount of grain. Grade Holstein cows were used for the study. The number of cows in the herd varied at any given time from 10 to 14, and were divided equally and uniformly as possible into two groups. The high roughage group received approximately 1 pound of grain for each $4\frac{1}{2}$ pounds of milk produced, 35 pounds of silage and as much hay as they would clean up daily. The low roughage group received approximately 1 pound of grain for each $2\frac{1}{2}$ pounds of milk produced, 20 pounds of silage, and hay as above. All feed was the same in composition at any given time for both groups, except that the grain mixture for the high roughage group was considerably richer in protein in order to keep the intake of protein at about the same level in both groups.

The results showed that the low roughage group produced more milk on both a daily and yearly basis. The daily milk yield for the 305-day lactation was 27.7 for the

high roughage group while that for the low roughage group was 31.7 pounds, a difference of 14.4 per cent in favour of the low roughage group. The cows in the low roughage group made somewhat larger gains in weight and maintained their general appearance better than did those receiving relatively large amounts of roughage. The cows in the low roughage group made slightly better use of the feed they consumed as evidenced by the fact that they required 7 per cent less dry matter and 2.7 per cent less digestible nutrients to produce 100 pounds of milk.

Graves et al. (14) conducted an experiment where 12 Holstein cows were fed four different rations with each ration being fed for one complete lactation period. The four rations were:

1. Full grain ration, consisting of a grain mixture (fed at an average rate of 1 pound to each 4.33 pounds of milk produced), pasture in season, and alfalfa hay and corn silage when cows were not on pasture.
2. Alfalfa hay alone, and pasture during the season.
3. Barley as the sole grain (fed at the rate of 1 pound to each 5.6 to 6.5 pounds of milk produced), alfalfa hay and pasture during the season.
4. Alfalfa hay and corn silage, and pasture during the season.

The lactation records of the 12 cows were compared to that of their production on full ration. It was observed that the 12 cows produced 69.75 per cent as much milk and 65.77 per cent as much butterfat on ration 2 as compared to their production on the full ration. They also produced 86.03 per cent as much milk and 80.24 per cent as much butterfat on ration 3, and 73.57 per cent as much milk and 69.93 per cent as much butterfat on ration 3 as on their full production ration.

Dawson and Graves (10) studied 62 lactation records of 46 Holstein cows which were fed roughage alone during the lactation period. The roughage consisted of either alfalfa hay and corn silage fed ad libitum, alfalfa hay of good quality, pasture grass cut at an early stage, or silage made from pasture grass cut at an early stage. It was observed that the average milk and butterfat production between the four groups of cows on the different kinds of roughage was remarkably close. The ME records on roughage alone averaged 11,416 pounds of milk and 405 pounds of fat. The 46 cows also made records under full feed conditions and the average ME production was 18,746 pounds of milk and 654 pounds of fat. The average production on roughage alone was 61 per cent as much milk and 62 per cent as much butterfat as the average production made under full feed conditions.

Moseley et al. (26) fed ten Holstein cows, in successive lactations, the following three rations: full grain, all roughage and limited grain. The roughage ration consisted of alfalfa hay, corn silage, roots and irrigated tame-grass pasture. The full grain ration, in addition to the same roughage, consisted of one pound of standard grain mixture for each 3 pounds of milk produced while the limited grain ration included the same roughage plus the grain mixture fed at the rate of 1 pound for each 6 pounds of milk produced. The average milk production on the all roughage ration was 13,656 pounds a year; 17,851 pounds on the full grain ration and 16,648 pounds on the limited grain ration. The authors expressed their opinion that where roughages of the right quality are available, cows of more than average producing ability have sufficient capacity to consume enough nutrients from roughage alone to meet their requirements.

Monroe and Livezey (25) compared two levels of grain feeding over a period of three years. One level was on a straight ratio basis of allotting grain at the rate of 1 pound to each 4 pounds of milk produced. The other level was to feed 1 pound of grain to every 3 pounds of milk produced above 20 pounds; when producing under 20 pounds no grain was given. Both levels of grain were fed in addition to a basic ration of 20 pounds of corn silage and ad libitum

hay feeding daily. No significant difference in the yield of milk was noted under the two levels of feeding. On an average, the high level feeding yielded 10,425 pounds of milk per lactation and low level feeding yielded 10,693 pounds. The heavy grain group, however, consumed 803 pounds more concentrates in producing the same amount of milk.

Kitchen et al. (21) conducted an experiment to compare the effect of feeding roughages alone to two levels of grain feeding. Cows receiving a ration consisting of ad libitum feeding of alfalfa hay supplemented by corn silage (3 pounds of silage per 100 pounds of body weight daily) produced 81.6 per cent as much as cows on the same roughage plus heavy grain fed at the rate of 1 pound of grain for each 3 pounds of milk. Cows fed a medium grain ration (1 pound of grain for each 6 pounds of milk) produced 95 per cent as much as the ones on heavy grain. It was observed that the response to heavy grain feeding was relatively small. With the medium grain feeding, each pound of grain produced 0.71 pounds more 4 per cent FCM whereas with heavy grain feeding each pound of grain produced only 0.51 pounds of 4 per cent FCM more than the all roughage group.

Headley (16) reported a study concerning the exclusive feeding of alfalfa hay, in which four grade Holsteins were fed for four years on selected alfalfa hay alone. They

averaged 8,644 pounds of milk and 303 pounds of butterfat per cow per year and consumed 1.6 pounds of hay for each pound of milk produced. Four similar Holstein cows were allowed all the alfalfa hay they would consume and in addition were fed 2,160 pounds of grain (approximately 1 pound for each 5 pounds of milk produced). Their production averaged 10,352 pounds of milk and 359 pounds of butterfat per cow per year. The cows fed alfalfa hay alone produced 83 per cent as much milk and 85 per cent as much butterfat as the cows fed alfalfa hay and grain. Average weight of the cows was maintained at a higher level when grain was fed.

Hodgson et al. (18) conducted an experiment extending over a period of three years with Holstein cows to study the relative merit of an all roughage ration compared to a full feed ration. The all roughage ration included good pasture in summer and home grown hay and silage in winter. A comparison was made on the yield of 15 cows having 31 records on all roughage feeding and 41 records made previously on full grain feeding. The average ME production of milk was 9,549 pounds when receiving the all roughage ration, or 76 per cent of that when receiving grain. The average butterfat production was 308 pounds, or 72.5 per cent of that when grain was fed.

In an attempt to find the minimum grain mixture that should be fed with available roughage, Pratt (28) fed two levels of grain on a basic ration of 24 pounds silage and hay ad libitum daily. Higher production was obtained at lower cost with limited grain feeding than when the cows were fed liberal amounts of grain. The interesting aspect of this experiment was the results of the two levels of grain feeding over several lactations. During the first winter the more liberally fed cows were in apparently better flesh than the ones on the limited grain. After the first winter there was no noticeable difference. The cows starting on the liberal grain allowance declined in production consistently from lactation to lactation while those on the limited concentrates started at a lower level of production but equalled the more liberally fed cows during the second lactation and continued to increase for the third and fourth lactations.

Lush (24) initiated an experiment extending over 3 years at the Louisiana Station to obtain more definite data on the proper amount of grain to be fed with roughage. Full grain feeding (1 pound of grain to each 4 pounds of milk produced by Holsteins and 1 pound to 3 pounds of milk for Jerseys) increased milk production 60 per cent over roughage alone, 10 to 15 per cent over low grain (Holstein 1:6; Jerseys 1:4.5) and 10 per cent or less over limited grain

(1 pound of grain per gallon of Holstein milk with a minimum of 2 pounds of grain per day). It was noted that all cows produced more on full grain than on roughage alone, while five out of eleven cows produced more on low or limited grain than on the full ration.

Effect of different levels of feeding on milk production

Jensen et al. (20) reported the results of two series of experiments carried out in several experimental stations over a period of three years. A total of 346 individual cows were used to obtain 469 records of production and feed.

In the first series cows were fed according to an accepted feeding standard, either the Haecker standard or the Morrison standard. All animals were fed a maintenance ration according to their weight but the production ration varied from 30 per cent below to 30 per cent above the standard level. In the second series of experiments, roughage was fed ad libitum with grain at the following rates: no grain, 1 pound grain per 6, 4, 3 or 2 pounds of milk produced. The record of nutrients which the animals consumed was used for comparison with requirements of the normal standard.

The data from both series of experiments showed that substantial increases in milk production were obtained by feeding above the standard, and that each successive equal increment in feeding level produced a smaller response in

milk produced. It was found that 15 to 20 per cent more milk was obtained from the cows at higher levels of feeding than cows fed at the standard level, and 45 per cent more than from cows fed at 70 to 80 per cent of the standard. With an increase in feeding level, cows reached a higher peak of production and maintained consistently higher production during the lactation period. The entire lactation curve was raised to a higher level. There was a fairly constant increase in body weight as the feeding level increased; the difference in weight between cows fed at the lowest and highest levels was over 100 pounds.

Borland et al. (8) reported an experiment where 24 cows (14 Holstein and 10 Brown Swiss) were fed a maintenance ration of alfalfa hay and corn silage and a production grain ration at different levels: 70, 80, 90, 100, 110, and 120 per cent of the Haecker feeding standard. These different levels of grain feeding were continued for two full lactations. It was observed that the cows at the 120 per cent level of feeding produced approximately 50 per cent more milk than those fed grain at 70 or 80 per cent of the standard requirement. Since the consumption of additional grain resulted in more milk at the higher levels of grain feeding, a further trial was conducted for a year in which the cows were allowed all the grain they would eat in addition to 7.5 pounds alfalfa hay and 23 pounds of corn silage

daily. Some of the cows did not consume more nutrients than 15 per cent above the standard, others ate 15 to 30 per cent above the standard allowance and a few ate more than 30 per cent above the standard allowance. All these cows produced more milk and gained in weight. However, the law of diminishing return operated with increasing allowance of grain, since the increment of grain at higher feeding levels brought continuously decreasing yields of milk per unit of grain.

The influence upon milk production of changes in level of feeding and proportion of bulky feed was investigated by Yates et al. (45), using available experimental materials from Britain, The United States, and Denmark. The results showed that increases in the level of feeding to rates well in excess of the conventional English standard, were capable of giving substantial increases in milk production. Variation in feed supply not only resulted in changes in milk yield but also changes in the weight of the cow. When a cow was fed at a high level, not only the milk production increased but the cow persistently gained weight. The feeding of bulky feeds alone reduced the yield due to the limitation of total energy intake.

Hansson et al. (15) conducted experiments with identical twins fed at different levels. One member of each twin pair was fed a normal ration while the other member received 80, 90, or 110 per cent of this amount. It

was found that milk production and body weight increased, but the energy output in weight gain and milk per unit energy input declined with increasing intake.

Types of ration and their effect on percentage of fat in milk

Balch et al. (2, 3, 4, 5 & 6) conducted a series of studies on the secretion of milk by cows on diets low in hay and high in concentrates.

One experiment (2) was conducted with 12 Shorthorn cows. All the cows received daily 17 to 21 pounds of hay, 30 pounds of mangolds and a balanced concentrate mixture at the rate of 4 pounds per 10 pounds of milk produced during the preliminary period. During the 4 weeks of treatment one group of cows continued on the same diet and two other similar groups received daily only 6 and 2 pounds of hay supplemented with 9 pounds of concentrate mixture low in fiber and protein. The same allowances of mangolds and concentrates for production were given to these as to the control group. It was observed that the mean fat content of milk produced in the last 2 weeks of the treatment period by cows receiving the diets low in roughage was 0.49 per cent (group receiving 6 pounds of hay) and 0.59 per cent (group receiving 2 pounds of hay) below that produced by the control cows. These differences were statistically significant. In the group receiving 6 pounds of hay daily,

the drop in fat content was accompanied by an increase in the yield of milk and there was only a small fall in the yield of milk fat but in the group receiving 2 pounds of hay there was a significant fall in the yield of milk fat.

Another experiment (3) was conducted to assess the importance of the protein content of the concentrates on the fat in milk when animals were receiving a low roughage ration. A control group of 4 cows received 18 pounds of hay daily and a concentrate mixture throughout the experiment, while 2 groups of 8 cows each received 4 pounds of hay daily for a treatment period of 7 weeks. One of these groups received concentrates containing 11.6 per cent crude protein and the other received concentrates containing 22.3 per cent protein. It was observed that both the low roughage diets depressed the fat content of milk and with the concentrate mixture high in protein the fall appeared to be slower than with concentrates low in protein.

Four comparable groups of cows were used in another trial (4) for an investigation of the effects of various amounts of hay, fed with concentrates, on the fat content of milk. The cows received 16 pounds of hay daily and about 4 pounds of a balanced concentrate mixture during the initial and final control periods. During the treatment period of 7 weeks the four groups received 12, 8, or 4 pounds of

hay or 8 pounds of coarsely ground hay per cow daily, with sufficient low protein concentrate to compensate for the reduction in hay. It was noted that the change from 16 to 12 pounds of hay did not appreciably affect the fat content of milk. The mean values of butterfat for the last two weeks of treatment showed that the milk fat percentage for groups receiving 8 and 4 pounds of hay daily and 8 pounds of ground hay daily dropped by 1.16, 1.12, and 1.72, respectively by comparison with the group fed 12 pounds of hay.

The effect of variations in the intake of digestible nutrients on the percentage of fat in milk was studied (5). In addition to 4 pounds of hay, cows were given concentrates in the form of cubes and as a mixture. The main difference between the two types of concentrates was that the mixture contained less than half as much crude fiber as the cubes (5.5 per cent as compared with 11.3 per cent in the dry matter) and more than twice as much true starch (36.5 per cent as compared with 18.6 per cent). Reducing the hay to 4 pounds did not affect the fat content of the milk when the other feed in the diet was concentrate cubes, but there was a striking mean fall of 1.04 per cent fat when the cubes were replaced by the concentrate mixture. The essential difference between the diet of low hay with concentrate mixture and the other diet given in the experiment was that

it provided a high intake of starch yet had little of the physical property of roughage. It, therefore, appeared that the depression of fat content followed the large intakes of starch or possibly other highly digestible carbohydrates at a time when the fiber intake was low.

Three comparable groups of cows were used in another experiment (6) to investigate the effect of diets consisting of 4 pounds of hay and concentrates containing 35 per cent weatings, 15 per cent decorticated groundnut cake and 50 per cent of either flaked maize, maize meal or dredge corn. During the experimental period of 6 weeks, one group of cows received the concentrate mixture containing flaked maize, a second group the mixture with maize meal and the third group with dredge corn. The mean daily intakes of starch for the different groups were respectively 6.0, 6.4, and 5.8 pounds. It was observed that the diet containing the maize caused a marked decline, and the one containing maize meal a small fall in the fat content of the milk, but the diet containing the dredge corn was without effect. In the last two weeks of the experimental treatment, the adjusted mean fat percentage for the group of cows receiving flaked maize was 0.51 and 0.71 below the percentage for the groups receiving maize meal and dredge corn, respectively. The greater depression with flaked maize than with others was thought to be associated with the effect on the flora of the rumen.

Loosli et al. (23) in three experiments used 20 Holstein cows to study the effect of low roughage intake upon the production of milk and butterfat. When cows were fed 5 pounds or less of hay daily and sufficient grain mixture to satisfy their energy requirements, the fat content of the milk and the milk yield showed a significant drop as compared with similar cows fed an average of about 12 pounds of hay, 30 pounds of corn silage and small amounts of grain mixture daily.

In a series of tests covering a period of 13 years, Powell (27) studied 37 cows with a total of 85 lactations. He observed that the fat content of the milk was varied as much as 60 per cent, by regulating the physical characteristics and the total intake of the roughage part of the ration. The results further showed that a cow may be maintained at the low fat level for at least 3 complete lactations without any apparent physical injury and can then be brought back to normal fat percentage permanently by changing the physical characteristics of the roughage and/or the amount of roughage received. It was also observed that the SNF content also varied in the same general manner as the fat.

Tyzink and Allen (41) observed that when the roughage intake of 8 milking cows was reduced to about 3 pounds of hay daily with as much concentrate as the cows would

eat, the fat test was depressed by 1-2 per cent after about two weeks. The low fat test persisted as long as the cows were continued on a low roughage, high concentrate diet. In every instance, the depression of milk fat resulting from the low roughage diet was accompanied by a change in the rumen fatty acid ratio. Proportionately, propionic acid increased, acetic acid decreased and butyric acid remained constant.

Van Soest et al. (44) made studies on 6 lactating cows fed on a normal and restricted roughage diet with the latter consisting of 3 pounds of hay daily plus concentrates fed ad libitum. It was noted that the milk fat declined from an average of 4.62 to 2.14 on the restricted roughage ration.

Studies by Turner (40) indicated that an abundant and well balanced ration had a tendency to maintain the constancy of the composition of milk, but the reduction of the feed below the normal level caused the per cent of fat to increase with a lowering of milk yield. The rise in test occurred within 2-3 days after the cut in feed. After a short time the fat percentage returned to normal.

Stoddard et al. (38) have shown that when cows received concentrates ad libitum with less than 6 pounds of hay daily, there was a marked decrease in the fat content of milk. It was further claimed that this decrease

in fat content could be prevented by the administration of acetic acid, but not propionic acid, through a stomach tube into the reticulo-rumen.

Effect of ration on solids-not-fat content of milk

A series of experiments were conducted by Riddet et al. (31 & 32) to provide information on the effect of plane of nutrition and type of feed on milk composition and yield. In one of the experiments (31), 6 cows were fed in 3 groups with one group on a normal plane of nutrition throughout and the other two groups on a full and half production ration using the double-reversal system. The experiment extended over a period of 100 days; 10 days pre-experimental period followed by three experimental periods of 30 days each. The results indicated that substitution of fresh pasture for a portion of a ration of concentrates and hay had no influence on the production or composition of milk. In other words, succulence of the ration did not appear to be an important factor. The transference of cows from a full ration to a half ration caused a decline in milk yield and fat yield as was to be expected. Reduction of the ration by one-half had no consistent influence on the fat percentage of milk. However, the subnormal plane of nutrition caused a definite fall in SNF ranging from 0.3 to 0.5 per cent. Solids-not-fat content returned to

normal when the change was made to full ration. The reduction in SNF content of milk affected mainly the total protein fraction with the variation in protein content being mainly responsible for the change in SNF.

In another experiment by the same workers (32), six cows were divided into two groups and fed on the double-reversal system. After a pre-experimental period of 21 days, the two groups of cows were subjected to alternate 4 week periods of full and subnormal rationing, with a final 2 week period of full ration. The cows were given sufficient hay to provide the SE necessary for their maintenance requirements and concentrates for milk production. During the subnormal feeding only half the calculated ration was supplied. The experimental results confirmed the previous observations that a subnormal plane of nutrition depresses milk yield and content of SNF in milk. The results indicated that in a period of subnormal nutrition milking cows produced milk definitely lower in protein content than normal milk and slightly lower in lactose content; therefore, the milk from cows on subnormal would be distinctly lower in SNF. It was also observed that underfeeding from mid-lactation onwards was likely to produce more adverse effects in reducing total yield and curtailing the total lactation period than was subnormal feeding at an earlier time.

Significant differences in the monthly levels of SNF content in milk was observed by Bailey (1). These differences were found to depend on seasonal feeding and managerial practices. Low levels of SNF were found when the weather conditions limited the supply of natural grazing. The spring flush of grass, when grazing was known to be of very high quality, coincided with a marked rise in the percentage of SNF levels. When pasture was dry and when there was little or no grazing available for cows, the SNF content of milk appeared to reach the minimum.

Trimberger (39) stated that a ration lacking in quality or quantity caused a reduction in SNF content of milk. A shortage of energy and/or protein in the diet reduced the SNF content by decreasing both the protein and lactose content of milk, but the protein was altered to a greater extent. Turning cows on fresh pasture in the spring increased the SNF content of milk. This was mainly due to an increase in the protein percentage with little change in the lactose content of milk.

Rook (33) investigated the effect of a high plane of nutrition on the composition of milk. Four cows were placed on an experiment at the end of their first month of lactation and were subjected to four feed treatments over successive 32-day periods, according to the Latin Square design. The four different daily treatments were:-

1. A normal ration calculated according to Woodman's table on the performance of each cow prior to the experimental period.
2. A normal ration plus 0.8 pounds of protein equivalent.
3. A normal ration plus 3.5 pounds of SE.
4. A normal ration plus 0.8 pounds of protein equivalent and 3.5 pounds of SE.

The results showed that, where additional energy was supplemented by providing more SE in the ration, there was a significant increase in the SNF content of milk while additional protein supplement had very little effect. The effects of energy and protein supplements seemed to be additive and there was no significant interaction.

Rowland (34) reported that reducing SE of rations to 75 per cent of that found in the normal diet caused reduction in the SNF content of milk, especially protein and lactose. Rations containing 60 per cent of normal protein equivalent levels were observed to decrease the SNF percentage in milk, especially lactose. Removing cows from winter rations of low SE and protein equivalent and placing the animals on grass feeding programs, produced marked increases in SNF, especially protein, after 2 weeks' pasturing.

Flux and Patchell (13) used 14 pairs of monozygous twins of mixed ages to determine the effect of underfeeding from the third to eighth week after calving on milk and butterfat production and on the composition of milk. The results of the six week experimental feeding period showed clearly that a short period of underfeeding soon after calving depressed milk yield, raised the butterfat percentage of the milk and lowered the SNF content with the latter fall being partly accounted for by the lowering of the total protein percentage. The increase in butterfat content of the milk of the underfed cows appeared to be closely related to changes in body weight, hence the extent of change in this milk constituent was probably dependent on the condition of the animal before underfeeding commenced and the degree of underfeeding. However, the complete lactation averages failed to show a statistically significant difference in all characteristics except in the case of SNF percentage.

Relationship between fat, solids-not-fat and protein

Cranfield et al. (9) analysed over 700 samples of mixed milk from 15 herds to determine the percentage of fat, SNF, and protein. With regard to the correlation of butterfat and SNF, it was observed that there was a corresponding fall in fat percentage with each drop in SNF percentage to about the average of 8.8 per cent. Below this point

there appeared to be a rise in fat content as the SNF dropped. A high correlation between protein and SNF was also noted; protein content falling with SNF. In the case of low percentage of SNF, below 8.2 per cent, the protein fall appeared to be arrested.

Analysis of 20,694 samples of milk, made by Jack and coworkers (19), from all areas and at all seasons of the year indicated that the relationship between per cent of SNF and fat in milk was not strictly linear. However, a linear estimating equation was suggested as it was more convenient to use. The per cent of SNF may be estimated from the per cent of fat by use of the following formula: $Y = 7.07 + 0.444 X$, where Y = per cent solids-not fat and X = per cent of fat.

Summary

A review of the literature indicates that the quantity of milk produced by cows usually increases as the proportion of concentrates in their ration increases. However, as the amount of concentrates is increased above a certain limit, the corresponding increase in milk yield becomes narrow. Instances have been reported where liberal feeding of grain had no beneficial effect when compared to normal feeding. The butterfat percentage in milk tends to drop as the quantity of roughage in the ration is reduced to below 5 - 6

pounds daily. A low plane of nutrition and low energy intake by cows causes the SNF in milk to decrease. The reduction in protein content seems to be mainly responsible for the change in SNF.

CHAPTER III

EXPERIMENTAL METHODS

Location and animals

This study was conducted at the University of Tennessee (U. T.) Agricultural Experimental Station at Knoxville. The study was begun on the 5th of April, 1961, and ended July 11, 1961. Three groups of 3 cows each from the U. T. Dairy herd were used for the experiment. They consisted of two groups of Holsteins and one group of Jersey cows. A description of the cows used in the experiment is given in Appendix A.

Rations Used

The three rations used in the experiment were:-

Ration A. No grain (hay fed ad libitum).

Ration B. Normal ration (hay fed ad libitum plus concentrates fed according to production).

Ration C. High grain (5 pounds of hay daily plus concentrates fed ad libitum).

The concentrate mixture was made up of 5 parts of shelled corn, 5 parts of oats and 3 parts of cottonseed meal. To this mixture was added 1 per cent common salt and 1 per cent di-calcium phosphate. Hay fed during the experimental period was of the U. S. grade No. 1 quality alfalfa hay. No silage was fed during the actual experimental period.

Design of the experiment

A 3 X 3 Latin Square design as shown in Table I was used to conduct the experiment. The entire experiment covered a period of 14 weeks; a preliminary period of 2 weeks followed by an experimental period of 12 weeks. The experimental period was divided into three 4 week periods and each of the 3 rations was fed to 3 cows during each period. Therefore, by the end of the experiment each ration was fed to each cow for a 4 week period.

Feeding

During the first week of the preliminary period the cows were fed corn silage and concentrate mixture at the rate of 1 pound for each 3.5 pounds of 4 per cent FCM produced. During the second week silage was replaced by alfalfa hay and concentrate feeding was continued at the same rate. The amount of concentrate fed to each cow when on the normal ration (Ration B) was based upon her 4 per cent FCM production during the 2 weeks preliminary period. During the preliminary period concentrates were fed to each cow at the rate of 1 pound for each 3.5 pounds of 4 per cent FCM produced. Thereafter, the amount of concentrates allowed to each cow on the normal ration was decreased at the rate of 2 per cent per week to allow for the lactational decline in milk yield. Therefore, it was possible at the beginning of the experimental period to calculate the amount

TABLE I

EXPERIMENTAL DESIGN (3 X 3 LATIN-SQUARE) USED FOR 9 COWS
ON A NO GRAIN, NORMAL AND HIGH GRAIN RATION FOR 4 WEEKS

| | | Group 1. (Holsteins) | | | Group 2. (Holsteins) | | | Group 3. (Jerseys) | | |
|----------------------|--------------------------|------------------------|------------------|-----------------|----------------------|----------------|-----------------|--------------------|-------------------|-----------------|
| | | Name and Number of Cow | | | | | | | | |
| Periods (4 wks.each) | | Pat (691) | Sunbeam (757) | Carrie (797) | Fay (645) | Julia (658) | Trixie (704) | Molly (453) | Juliette (397) | Vanity (378) |
| 1. | 4-19-61 to 5-16-61 | A* | B | C | C | B | A | A | B | C |
| 2. | 5-17-61 to 6-13-61 | B | C | A | A | C | B | B | C | A |
| 3. | 6-14-61 to 7-11-61 | C | A | B | B | A | C | C | A | B |

*Letters indicate treatment

A = No grain
B = Normal
C = High grain

of concentrates to be fed to each cow on the normal ration regardless of what period she received the normal ration.

The feeding of cows during the actual experimental period was done according to the design. The change over from one ration to another took 3 days, except for cows going on high grain, so that on the 4th day animals were receiving the ration they were scheduled to get. The concentrate mixture for the cows on high grain was raised by 4 pounds every day until feed was refused. All cows on high grain were fed a sufficient amount to allow a weigh-back of at least 2 to 5 pounds from each feeding. At first the concentrate mixture was fed to the high grain group only twice daily just prior to milking. Since some difficulty was experienced in getting high consumption when the cows were fed large quantities of grain at one time, they were fed the concentrate mixture 4 times a day. The cows on high grain were fed hay only twice daily. Animals on no grain and the normal ration had free access to hay. Sufficient hay was fed to these cows to allow a refusal of 3 to 5 pounds from each feeding. The weights of all feeds given to the cows and the amounts refused were recorded.

Management

All the cows were housed in a stanchion barn during the entire experiment. They were fastened in a comfort type

stanchion stall by a neck chain which allowed ample freedom for resting. They had access at all times to fresh water obtainable from automatic water bowls. The cows on high grain were bedded with wood shavings in order to prevent them from eating their bedding. All other cows were bedded adequately with straw. The cows were milked twice daily at 2 A. M. and at 2 P. M. in an adjacent milking parlor. The animals had practically no exercise except their movement from the stanchions to the milking parlor. The milk was weighed at each milking and recorded to the nearest tenth of a pound. Body weights of the cows were taken at 8 A. M. on 3 consecutive days, at the end of the preliminary period and at the end of each change over period.

Analytical procedure

Composite samples of milk taken from four consecutive milkings at weekly intervals were analysed for their contents of fat, SNF, and protein. Formalin was added to the milk samples as a preservative; 2 to 3 drops of 5 per cent formalin to each sample of milk (4 to 6 ounces). The samples were brought to the laboratory and stored in a refrigerator. Analysis of all samples was completed within 3 to 5 days after collection. Percentage of fat in milk was determined by the Babcock method.

Solids-not-fat content was determined by a specific gravity method using a Watson lactometer field kit. The

kit consisted essentially of a water bath where the temperature was maintained at 102 degrees Fahrenheit. The samples of milk were placed in the water bath in a glass cylinder and the lactometer readings were taken. Solids-not fat was determined by the equation derived by Whitter after obtaining the lactometer reading ($SNF = .33 F + \frac{273L}{L + 1000} - .40$, where F represents the percentage of fat and L the lactometer reading).

Protein was determined by the Kjeldahl method and by the buffalo black dye binding method as described by Vanderzant (43). The procedure of determining protein by the dye binding method consisted of mixing a small amount of milk with an excess amount of dye and centrifuging for 15 minutes. A small portion of the insoluble supernatant was diluted and its optical density read in a spectrophotometer. The protein content of the samples was determined by the following formula obtained from Vanderzant (42): Per cent protein = $(1.318 - \text{optical density}) \times 3.937$. Also a standard curve which represented the relationship between the light absorption values (optical density) of the unbound dye in the supernatant liquid and the protein content as determined by the Kjeldahl method was prepared.

Samples of the concentrate mixture and hay fed to the animals during the experimental period were taken at weekly

intervals. They were composited separately and analysed. Samples of hay from 20-25 bales were taken at a time with a "Penn-State Forage Sampler". A small sample of concentrate mixture was taken every week as the mixture was weighed out to cows. Proximate analysis was made on the composited samples.

Analysis of data

The analysis of variance, the standard deviation, and the t test on the data collected in this experiment were done according to Snedecor (36). Also, the standard curve on protein per cent was determined by calculating the regression of optical density on Kjeldahl protein per cent as outlined by Snedecor (36). The test of significance between mean values was determined by Duncan's multiple range test (12).

CHAPTER IV

RESULTS AND DISCUSSION

Health and condition of the cows

In general, the health and condition of the cows during the experimental period was satisfactory. Fay (No. 645) was sick for about 4 days with a bladder infection when she was on the high grain ration. Also, she and Vanity (No. 378) had a mild attack of mastitis when they were on the high grain ration. The 3 cows on the high grain ration when the experiment started refused a large quantity of grain during the second week of the high grain feeding period. At that time, concentrates were fed four times instead of twice a day. This arrangement of feeding was more satisfactory as fewer difficulties were encountered in getting the cows to consume more grains. However, as grain consumption progressively increased, most of the cows temporarily dropped in consumption for a day or two. This usually occurred during the second and third week of the grain feeding period and indicated probably some digestive disturbance.

Feed consumption

The feed consumed by the cows during the experimental period is given in Table II. The cows which were given free access to hay consumed an average of 26 and 27 pounds of hay

TABLE II

TOTAL FEED CONSUMPTION OF 9 COWS FED A NO GRAIN,
NORMAL AND HIGH GRAIN RATION FOR 4 WEEKS

| Periods | No Grain | | | Normal | | | High Grain | | |
|-----------------------------|----------|-------------------|------------------------|--------|-------------------|------------------------|------------|-------------------|------------------------|
| Cows | Hay | Concen- trates | Total Dry Matter | Hay | Concen- trates | Total Dry Matter | Hay | Concen- trates | Total Dry Matter |
| (Pounds) | | | | | | | | | |
| <u>Group 1. (Holsteins)</u> | | | | | | | | | |
| Pat | 844 | 30 | 784 | 1019 | 330 | 1206 | 169 | 1265 | 1272 |
| Sunbeam | 784 | 55 | 752 | 871 | 316 | 1061 | 173 | 1390 | 1387 |
| Carrie | 869 | 48 | 821 | 779 | 246 | 917 | 180 | 1080 | 1118 |
| Daily Average | 30 | 1.6 | 29 | 32 | 10.6 | 38 | 6 | 44.5 | 45 |
| <u>Group 2. (Holsteins)</u> | | | | | | | | | |
| Fay | 882 | 44 | 829 | 855 | 266 | 1002 | 175 | 884 | 940 |
| Julia | 676 | 55 | 654 | 613 | 217 | 742 | 155 | 972 | 999 |
| Trixie | 719 | 26 | 668 | 814 | 291 | 969 | 165 | 1137 | 1155 |
| Daily Average | 27 | 1.5 | 26 | 27 | 9.2 | 32 | 6 | 35.6 | 37 |
| <u>Group 3. (Jerseys)</u> | | | | | | | | | |
| Molly | 622 | 20 | 575 | 614 | 169 | 700 | 146 | 619 | 679 |
| Juliette | 498 | 31 | 494 | 622 | 182 | 719 | 153 | 699 | 756 |
| Vanity | 568 | 33 | 538 | 497 | 140 | 570 | 153 | 709 | 766 |
| Daily Average | 20 | 1.0 | 19 | 21 | 5.9 | 24 | 5 | 24.1 | 26 |
| <u>Over all</u> | | | | | | | | | |
| Daily Average | 26 | 1.4 | 24 | 27 | 8.6 | 31 | 6 | 34.7 | 36. |

daily on the no grain and normal ration, respectively. The Holstein cows in Group 1 consumed an average of 30 pounds of hay daily, those in Group 2 consumed 27 pounds daily while the Jerseys in Group 3 consumed 20 pounds of hay when they were on the no grain ration. The daily average hay consumption of the three groups of cows on the normal ration was 32, 27 and 21 pounds, respectively.

On an average, the cows when fed the high grain ration, consumed 34.7 pounds of the concentrate mixture daily. The Holstein cows in Group 1 consumed an average of 44.5 pounds and those in Group 2 consumed 35.6 pounds of concentrates daily. The Jersey group, however, consumed only 24.1 pounds daily. Of all the cows, Sunbeam (No. 757) had the highest daily maximum consumption of 73 pounds of concentrates. She was one of the three top milk producing cows. It will be noted in Table II that the cows on the no grain ration were fed some concentrates. This represented the small quantity fed during the first 3 days of the change over to the no grain ration.

The average daily consumption of total dry matter by the cows on the three treatments was 24, 31 and 36 pounds for the no grain, normal and high grain rations. When the cows were on the high grain ration, they consumed significantly more dry matter than when on the other two rations. Also when on the normal ration the cows consumed significantly

more dry matter than when they were fed the no grain ration. Both of these were significant at the 1 per cent level. This was expected and reasonable since the cows receiving grain consumed comparatively more feed.

The 2 per cent reduction per week on the amount of concentrates to be fed to the cows when on the normal ration allowed the cows more grain than they should have received on the basis of the 4 per cent FCM produced during that period. This indicates that the cows dropped in production during the experiment more than the anticipated lactational decline.

The results of the proximate analyses of the composite samples of hay and concentrates fed to the cows during the experimental period are presented in Appendix B. The composition seems close enough to the estimated or expected values except for the per cent of protein in the concentrate mixture, which appears to be somewhat high.

Body weight of cows

The average weight of the cows at the end of the pre-experimental period was 1,144 pounds. Their average weights after they were on the no grain, normal and high grain rations were 1,134, 1,160, and 1,178 pounds, respectively. On an average, the cows lost 10 pounds on the no grain ration but gained 16 pounds on the normal and 34 pounds on the high

grain ration. The 3 Jersey cows had an average weight of 850 pounds at the end of the pre-experimental period and gained on an average 16, 29 and 37 pounds while on the no grain, normal and high grain rations. The 6 Holsteins cows which had an average weight of 1,291 pounds at the end of the pre-experimental period lost 32 pounds on the no grain ration and gained 11 and 33 pounds on the normal and high grain ration, respectively. Juliette (No. 397), attained her maximum weight of 918 pounds (an increase of 55 pounds over her pre-experimental weight) on the no grain ration. This was responsible for the average increased weight of the Jersey group on the no grain ration. It may be mentioned that she was on the no grain treatment during the last experimental period and she was almost dry by the end of the period which might account for her increased weight. However, she was no further advanced in gestation than the other cows. None of the cows were more than 5 months in gestation at the end of the experiment. Fay (No. 645) reached her maximum weight on the normal ration. She was sick and off feed for a few days during the second week of the high grain period, which may have resulted in her reduced weight during that period. All the other cows attained their maximum weight while on the high grain ration.

The data on body weights of the animals were analysed statistically and it was found that the difference in

weight between the normal and the high grain rations was not significant. The weight of the cows on the normal ration was significantly more (at the 5 per cent level) than that of the cows on the no grain ration. The difference in the mean weight of cows between the high grain and the no grain ration was significant at the 1 per cent level.

Several investigators (16, 22, 28) have observed that cows put on more body weight by liberal feeding of grain than when fed roughage alone. The changes in body weight were reported to depend on the length of time the animals were on the liberal grain ration and also on the extent of liberal feeding. In the present experiment the cows were on the different treatments only for a short period, yet a similar trend of weight changes was observed.

Milk production

The amount of milk produced by the cows during the experimental period is given in Table III. The average weekly milk production of the cows when they were on the no grain, normal and high grain rations is shown in Figure 1. The cows on the no grain ration produced a total of 5,193 pounds of milk during the 4 week period and while on the normal and high grain rations they produced 6,219 and 6,059 pounds of milk, respectively. It is interesting to note that the cows produced more milk when on the normal ration than on the high

TABLE III

MILK, BUTTERFAT AND 4 PER CENT FCM PRODUCTION OF 9 COWS FED ON
A NO GRAIN, NORMAL, AND HIGH GRAIN RATION FOR 4 WEEKS

| Cows | No Grain | | | Normal | | | High Grain | | |
|-----------------------------|----------|-----------|-----|--------|-----------|-----|------------|-----------|-----|
| | Milk | 4% FCM | Fat | Milk | 4% FCM | Fat | Milk | 4% FCM | Fat |
| (Pounds) | | | | | | | | | |
| <u>Group 1. (Holsteins)</u> | | | | | | | | | |
| Pat | 1057 | 981 | 37 | 983 | 898 | 34 | 861 | 723 | 25 |
| Sunbeam | 748 | 645 | 23 | 1034 | 899 | 32 | 919 | 757 | 26 |
| Carrie | 776 | 651 | 23 | 795 | 692 | 25 | 1074 | 919 | 33 |
| Daily Average | 31 | 27 | 1.0 | 34 | 30 | 1.1 | 34 | 29 | 1.0 |
| <u>Group 2. (Holsteins)</u> | | | | | | | | | |
| Fay | 816 | 712 | 26 | 971 | 851 | 31 | 1028 | 869 | 30 |
| Julia | 336 | 278 | 10 | 771 | 631 | 22 | 605 | 483 | 16 |
| Trixie | 759 | 776 | 32 | 767 | 732 | 28 | 731 | 653 | 24 |
| Daily Average | 23 | 21 | 0.8 | 30 | 26 | 1.0 | 28 | 24 | 0.8 |
| <u>Group 3. (Jerseys)</u> | | | | | | | | | |
| Molly | 396 | 423 | 18 | 358 | 377 | 16 | 303 | 296 | 12 |
| Juliette | 63 | 66 | 3 | 322 | 326 | 13 | 151 | 139 | 5 |
| Vanity | 242 | 253 | 10 | 218 | 237 | 10 | 387 | 409 | 17 |
| Daily Average | 8 | 9 | 0.4 | 11 | 11 | 0.5 | 10 | 10 | 0.4 |
| Total | 5193 | 4785 | 182 | 6219 | 5643 | 211 | 6059 | 5248 | 188 |
| Over all | | | | | | | | | |
| Daily Average | 21 | 19 | 0.7 | 25 | 22 | 0.8 | 24 | 21 | 0.7 |

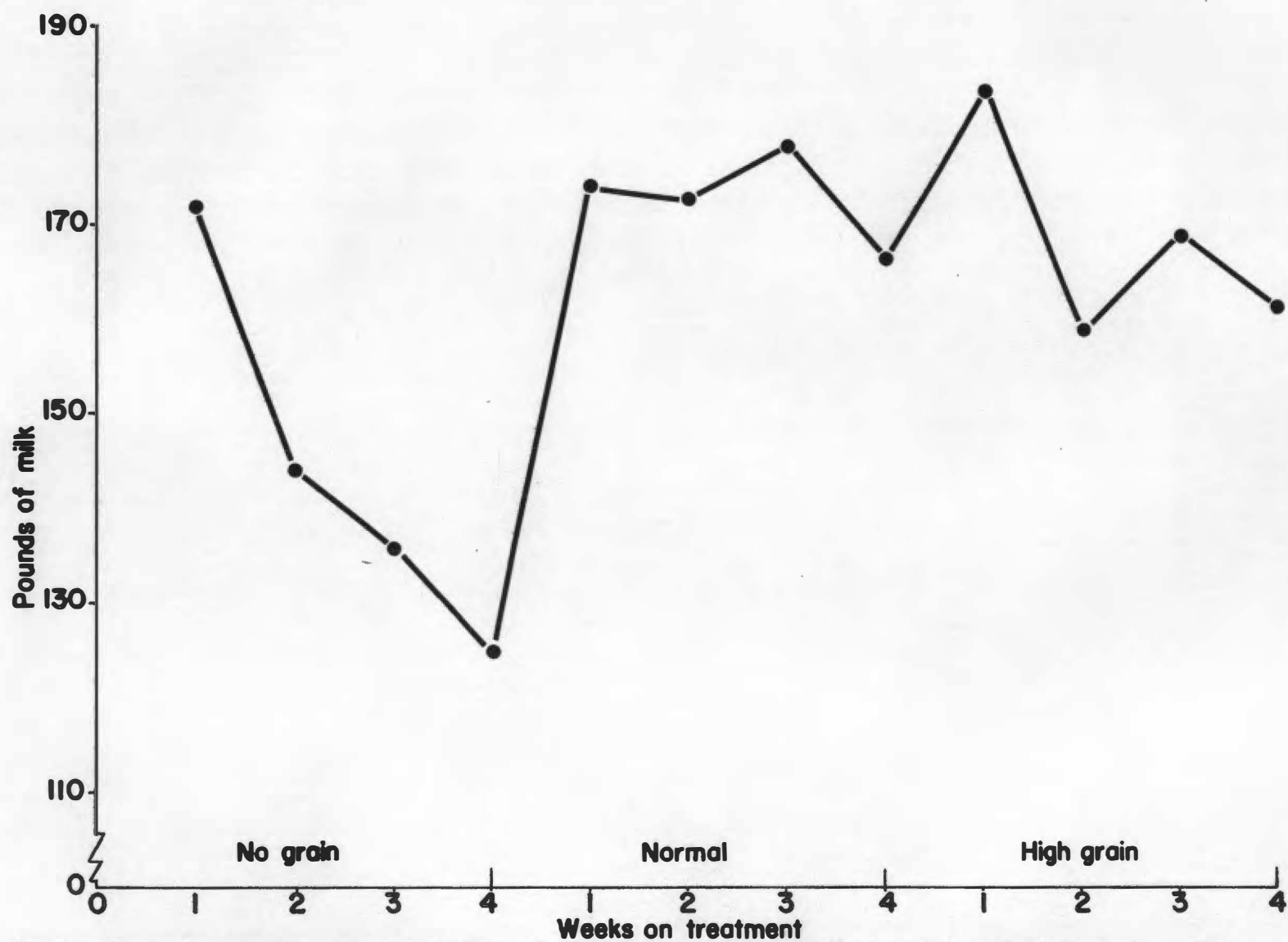


Fig. 1 Average weekly milk production of 9 cows on a no grain, normal and high grain ration for 4 weeks.

grain ration although they were consuming an average of 5 pounds per day more dry matter when on the latter ration. The difference in milk production when the cows were on the normal and high grain ration was not significant but their production on both these rations was significantly more (at the 1 per cent level) than the production on the no grain ration.

Butterfat

The pounds of fat produced by the cows on the three rations is presented in Table III and the average weekly butterfat per cent is shown in Figure 2. The average fat percentage of milk produced by all the cows on the no grain, normal and high grain rations was 3.48, 3.38, and 3.11, respectively. It may be seen from Table III that the cows produced 182, 211, and 188 pounds of butterfat on the no grain, normal and high grain ration, respectively. On the no grain ration the cows produced 86 per cent as much butterfat as on the normal ration and 89.5 per cent of the normal ration when fed the high grain ration. The difference in butterfat production between the cows when they were on the high grain and no grain ration was not statistically significant. However, butterfat production of the cows while on the normal ration was significantly more (at the 5 per cent level) than when on the other two rations.

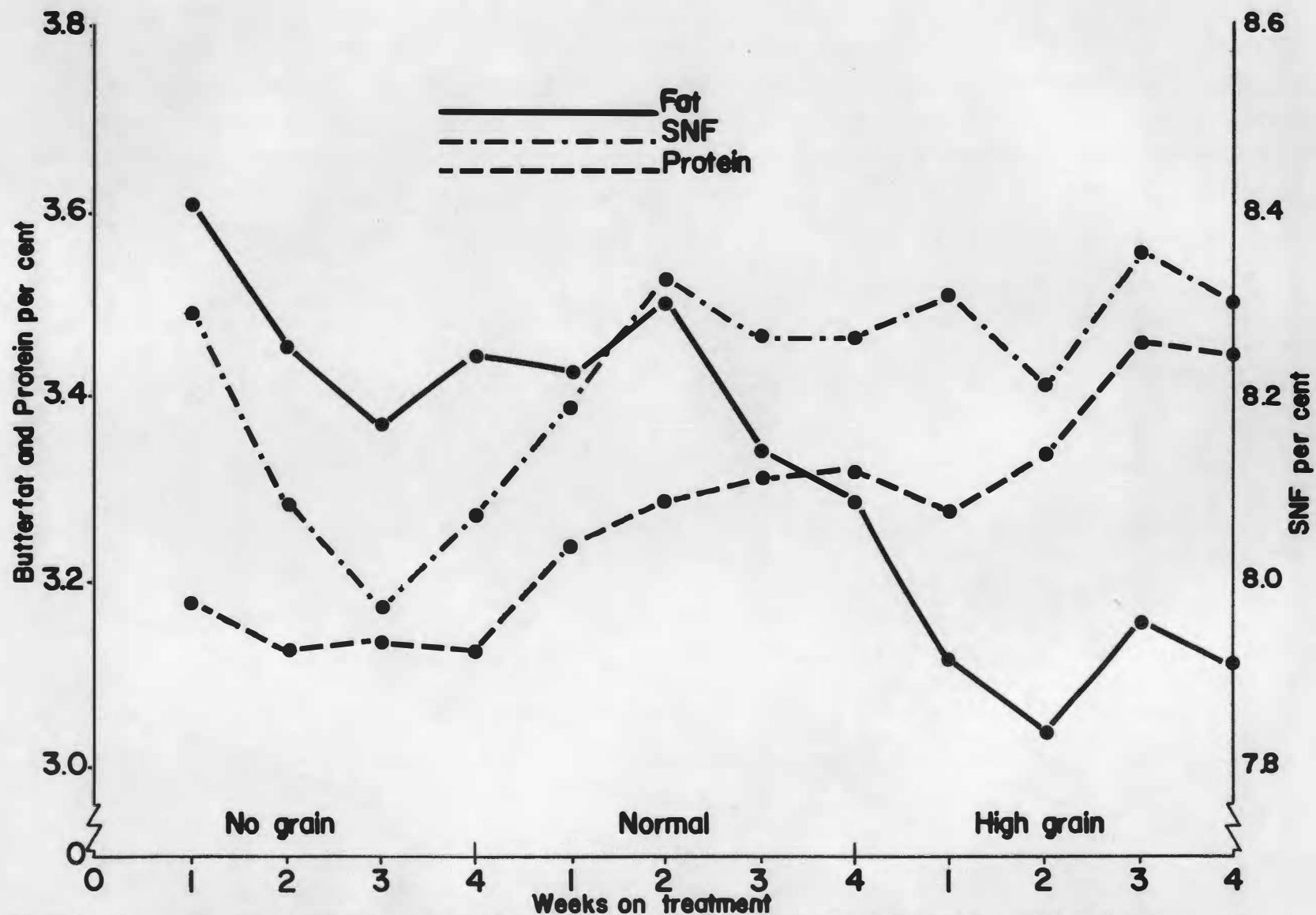


Fig2 Average weekly butterfat, SNF and protein per cent of milk produced by 9 cows on a no grain, normal and high grain ration for 4 weeks.

The general trend, as shown in Figure 2, was a lower fat test on the high grain ration. The reduction in the percentage of fat in the milk when the cows changed from the normal to the high grain ration appeared to be more than the increase in percentage of fat when the cows were changed from high grain to the normal ration. The variation in the fat percentage of milk when the cows were changed from the no grain to the normal ration was not consistent. The percentage of fat in the Jersey milk produced on different rations varied more than the milk from the Holstein cows.

Several investigators (2, 23, 38, 43, & 44) have reported that the percentage of fat in milk was depressed when the roughage intake of cows was limited to 3 to 6 pounds daily. In the present experiment, the lowest fat percentage was noted for the high grain ration which included only 5 pounds of hay daily. However, it may be seen from Table II that the Holstein cows received an average of 6 pounds of hay daily. During the 3 day change over period they were given more than their regular quota of 5 pounds which accounted for the average of 6 pounds for the entire period.

4 per cent Fat-corrected-milk

The total FCM production of the cows on the different rations was 4,785, 5,643 and 5,248 pounds for the no grain, normal and high ration, respectively. The cows produced at their highest level on the normal ration followed by the high grain and the no grain ration. Analysis of variance showed (Appendix C) that there was a highly significant difference between all 3 treatments. The cows on the normal ration produced significantly more (at the 1 per cent level) 4 per cent FCM than on the other two rations and when on the high grain ration they produced significantly more (at the 1 per cent level) 4 per cent FCM than on the no grain ration. The 4 per cent FCM production of the cows on the no grain ration was 85 per cent of the amount produced on the normal ration and 91 per cent of the production on the high grain ration. When the cows were on the high grain ration they produced only 93 per cent as much 4 per cent FCM as on the normal ration.

A study of the FCM ~~production~~ of the cows on the different rations revealed the fact that all the cows produced their highest during the first 4 week period, irrespective of the ration they received. Juliette (No. 397) which started on the normal ration followed by the high grain and no grain had the greatest variation in production. Her FCM

production on the high grain ration was only 43 per cent of her production on the normal ration and on the no grain ration her production was 20 per cent of that on the normal ration. Her lactational decline was much greater than for the other cows and as mentioned previously she was almost dry during the last period of treatment.

Several experiments (10, 14, 18, 21, 35) have been reviewed on the performance of cows on a roughage ration exclusively. The quantity of milk produced by cows on a roughage ration seems to vary considerably, from 61 to 82 per cent of their production on a normal ration. In the present experiment the cows on the no grain ration produced 85 per cent of their 4 per cent FCM production on the normal ration. This is slightly more than what has been reported by other workers. However, most of the earlier studies were based on complete lactation yields while the present study was based on the result of a 28 day period. This might be responsible for somewhat higher production of cows on the no grain ration.

Experimental results (10, 22, 35, 37) indicate that rations consisting of grains generally yield more milk than roughages alone. Recent publications in popular magazines support the view that heavy grain feeding is desirable for high milk production. But liberal feeding of grain has not always resulted in maximum production (24, 25, 28). In the

present experiment, the feeding of grain ad libitum resulted in lower production of cows than when they were on a normal ration. Physiological disturbances are likely to be more pronounced when the level of feeding intake is much higher than usual (30). Some of the cows in this study had digestive disturbances when they were on the high grain ration. One of the cows was sick and two had a mild attack of mastitis during the high grain feeding period. These factors may have contributed to the depression in milk production when they were on the high grain ration. However, 3 of the 9 cows produced their maximum amount of milk when on the high grain ration. These cows received the high grain ration during the first period of the experiment.

Feed efficiency

In comparing the feed consumption to milk production, it was observed that the cows on the no grain ration consumed 1.3 pounds of dry matter for each pound of 4 per cent FCM produced. When on the normal ration the cows consumed 1.4 and on the high grain ration 1.7 pounds of dry matter per pound of 4 per cent FCM. To produce 100 pounds of 4 per cent FCM, the cows on the no grain ration consumed an average of 135 pounds of hay and 8.6 pounds of grain. The 8.6 pounds of grain represents the small quantity fed to each cow during the change over to the no grain ration.

The cows on the normal ration consumed an average of 118 pounds of hay and 38.2 pounds of grain and the cows on the high grain ration consumed 28 pounds of hay and 166.8 pounds of grain to produce 100 pounds of 4 per cent FCM.

Solids-not-fat

The average SNF percentage of the milk produced by all the cows was 8.1, 8.3, and 8.3 for the no grain, the normal and the high grain ration, respectively. The milk from the Jersey cows averaged 8.71, 8.88 and 8.78 percentage of SNF while that from Holstein cows averaged 8.02, 8.15, and 8.22 percentage of SNF on the no grain, normal and high grain ration, respectively. The total production of SNF by cows on the three different rations was 421 pounds for the no grain, 514 pounds for the normal and 503 pounds for the high grain ration. Analyses of variance (Appendix D) showed that there was no significant difference in the production of SNF when the cows were on the normal or the high grain ration. The SNF production when the cows were on the no grain ration was much lower than when on the other two rations. These differences were significant at the 1 per cent level.

As shown in Figure 2, the general trend in the changes in the SNF content of the milk was a depression when the cows were on the no grain ration. All the cows showed a

general rise in the SNF percentage of the milk when they were changed from the no grain to the normal ration. But when they were changed from the normal to the high grain ration, all cows did not behave in the same manner; some showed a lower and others a higher test in SNF. When the cows were shifted from the high grain to the no grain ration, all except the cow Juliette (No. 397) showed a lower test in SNF. This cow was almost dry during the no grain period, producing only 2 to 3 pounds of milk daily. Her low milk production might have worked against the depression in SNF while on the no grain ration.

It has been shown that a low plane of nutrition and a low energy intake will depress the SNF content of milk (31, 32, 34). The cows fed the no grain ration in this experiment consumed less energy and their SNF production was significantly less than on the other two rations. The findings are, therefore, in agreement with those reported previously. Rook (33) showed that additional energy supplemented by providing more SE raised the SNF content of milk. In this study the cows on the high grain ration failed to produce more SNF than on the normal ration which does not agree with the observation of Rook.

Protein

A standard curve (Figure 3) for the spectrophotometer (Spectronic 20) was established by calculating the

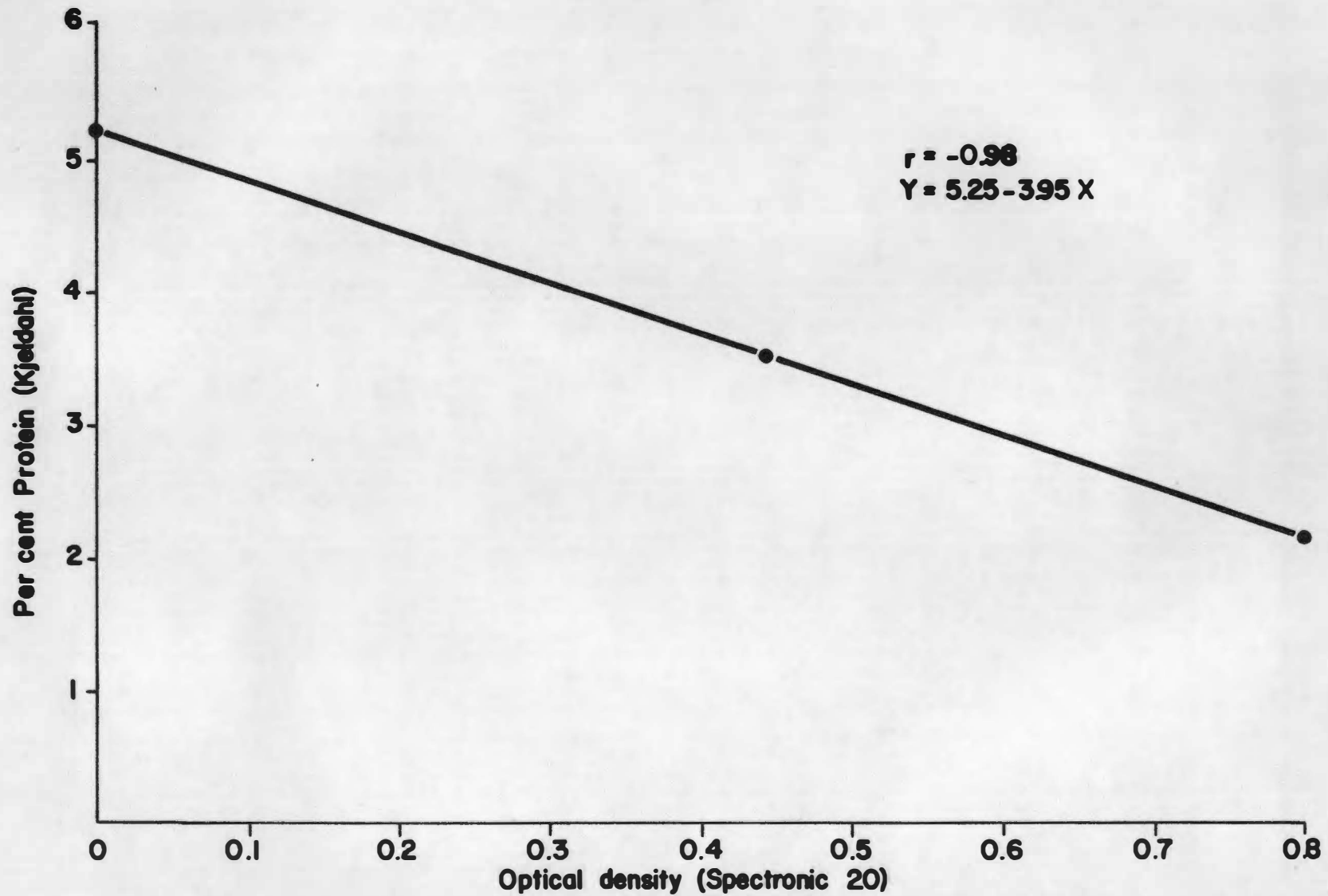


Fig.3 Regression of optical density and per cent protein of 108 milk samples from 9 cows.

regression of optical density of each sample on the percentage of protein as determined by the Kjeldahl method. The correlation between the optical density and the corresponding Kjeldahl protein value of each sample was highly significant ($r = -0.98$). The regression equation ($Y = 5.25 - 3.95X$) in Figure 3 shows that the protein content of milk decreases .0395 percent for each increase of 1 in optical density.

The average protein percentages of the milk samples as calculated by the regression equation were 3.15, 3.29 and 3.38 for the no grain, normal and high grain rations. The protein in milk from the Jersey cows averaged 4.05, 4.22 and 4.42 per cent while that from the Holstein cows averaged 3.13, 3.17 and 3.21 on the no grain, normal and high grain rations, respectively. The total production of protein was 163 pounds from the cows on the no grain, 204 pounds on the normal and 205 pounds on the high grain ration. The analysis of variance (Appendix E) showed that there was no significant difference in the production of protein when the cows were on the normal or on the high grain ration. However, the total protein produced by cows on the no grain ration was significantly less (at the 1 per cent level) than on the other two rations.

As shown in Figure 2, the general trend in changes in the protein percentage of the milk was an increase as the cows changed from the no grain to the normal and from the normal to the high grain ration. These changes in the percentage of protein seemed to follow closely those of the SNF. When changed from the normal to the high grain ration all cows, except two, increased their percentage of protein in the milk. The protein content of the milk from all cows, except Juliette (No. 397), went down when they were on the no grain ration.

A reduction in the feed energy intake and a low plane of nutrition have been shown to cause depression in SNF, especially in the protein content (30, 31, 34). The results of this study also showed a similar trend in the changes of the protein content of milk.

Correlation between the milk constituents

The coefficient of correlation between SNF and butterfat percentages of 108 milk samples was highly significant ($r = + 0.72$). It may be seen from Figure 2 that both SNF and fat percentages dropped when the cows were on the no grain ration, but the drop in SNF was more than the butterfat percentage. When the cows were started on the normal ration both SNF and butterfat increased. During the second half of this period the butterfat percentage began to decline

and continued to be much lower on the high grain ration. But the SNF level continued to rise steadily during the second half of the normal ration period and was much higher while the cows were on the high grain ration.

The correlation coefficient between the SNF and protein percentages of the samples of milk analysed was calculated. A positive correlation was found ($r = + 0.75$) between the percentage of SNF and the percentage of protein which was significant at the 1 per cent level. From Figure 2, it may be noted that the percentage of protein seemed to fall or rise along with SNF.

The correlation coefficient between the per cent of protein and butterfat of the milk samples analysed was found to be significant at the 1 per cent level ($r = + 0.78$).

Since protein is a component part of SNF, a positive correlation between SNF and protein should be expected. Changes in protein will reflect like changes in SNF. However, protein and fat and SNF and fat are independent and any significant relationships between these should be more meaningful.

Comparison of methods of protein determination

The average percentage of protein of the samples was 3.51 ± 0.61 as determined by the Kjeldahl method and 3.46 ± 0.61 by the buffalo dye binding method. The t test showed

that the difference between these two values was not significant.

The coefficient of correlation between the per cent of protein as determined by the regression line (Figure 3) and that calculated by the Vanderzant formula was found to be significant at the 1 per cent level ($r = + 0.98$). The percentage of protein as determined by regression line was consistently higher than the Vanderzant formula by .04 to .05 per cent for each sample. Both methods had the same standard deviation of 0.61.

CHAPTER V

SUMMARY AND CONCLUSIONS

Three groups of 3 cows each were used in a 3 x 3 Latin Square designed experiment for a period of 12 weeks. The study was made of the effect of rations containing various hay to concentrate ratios upon the production and composition of milk.

The three rations were:- (1) no grain (with ad libitum hay); (2) normal (1 pound of grain for each 3.5 pounds of 4 per cent FCM plus hay fed ad libitum); (3) high grain (grain fed ad libitum with 5 pounds of hay daily). Each of the 9 cows was fed each ration for a period of 4 weeks.

When the cows had free access to hay they consumed an average of 26 and 27 pounds of hay daily on the no grain and normal rations, respectively. Even when grain was fed on the normal ration the cows consumed more hay than when they were on the no grain ration. The cows while on the high grain ration consumed an average of 34.7 pounds of grain daily. The average daily consumption of total dry matter by cows on the three treatments was 24, 31 and 36 pounds, for the no grain, normal and high grain rations, respectively. When the cows were on the high grain ration, they consumed significantly more dry matter than when on the other two rations. Also when on the normal ration the

cows consumed significantly more dry matter than when they were fed the no grain ration. Both of these were significant at the 1 per cent level.

The cows when fed the no grain ration produced a total of 5,193 pounds of milk during the 4 week period. Their production on the normal and high grain rations was 6,219 and 6,059 pounds of milk, respectively. The average butterfat test of the milk produced by all the cows on the no grain, normal and high grain rations was 3.48, 3.38 and 3.11, respectively. The general trend was for a lower fat test on the high grain ration. The difference in milk production when the cows were on the normal and high grain ration was not significant but their production on both these rations was significantly more (at the 1 per cent level) than the production on the no grain ration. Likewise the butterfat production of the cows on the normal ration was significantly more (at the 5 per cent level) than when on the other two rations.

Expressed in terms of 4 per cent FCM, the production of cows on the different treatments was 4785, 5643 and 5248 pounds for the no grain, normal and high grain rations, respectively. The cows produced more on the normal ration. The 4 per cent FCM production of cows on the three treatments were significantly different at the 1 per cent level.

On an average the cows lost 10 pounds on the no grain ration but gained 16 pounds on the normal and 34 pounds on the high grain ration. The difference in body weight of the cows when on the normal and the high grain ration was not significant. However, the weight of the cows on the normal ration was significantly more (at the 5 per cent level) than that of the cows on the no grain ration.

The average SNF percentage of the milk produced by the cows was 8.1, 8.3 and 8.3 on the no grain, normal and high grain ration, respectively. The total production of SNF by cows on the three different rations was 421 pounds for the no grain, 514 pounds for the normal and 503 pounds for the high grain ration. The SNF production of cows while on no grain ration was significantly less (at the 1 per cent level) than on the other two rations.

The average protein per cent of the milk produced by the cows was 3.15, 3.29 and 3.38 on the no grain, normal and high grain ration. The total production by the cows on the different rations was 163 pounds for the no grain, 204 pounds for the normal and 205 pounds for the high grain ration. The protein production of cows on the no grain ration was significantly less (at the 1 per cent level) than the other two rations.

A standard curve based on the regression of optical density readings on Kjeldahl protein determinations was made. A comparison of the different methods of protein determination revealed that there was no significant difference between the Kjeldahl method and the Buffalo black dye binding method. The coefficient of correlation between the protein values as determined by the regression line and the Vanderzant formula was highly significant ($r = + 0.98$).

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APPENDICES

APPENDIX A

DESCRIPTIVE DATA ON THE 9 COWS USED IN THE EXPERIMENT

| Name and No. | Age Yr.-Mo. | Lacta- tion No. | Calving date | Effective service date | Initial weight pound | Preliminary Period | |
|----------------------------|----------------|-----------------------|-----------------|------------------------------|----------------------------|---|-------------------------------------|
| | | | | | | Average daily milk yield pound | Average butterfat per cent |
| <u>Group 1 (Holsteins)</u> | | | | | | | |
| Pat (691) | 6 - 11 | 4 | 12-2-60 | 3-15-61 | 1332 | 51 | 3.30 |
| Sunbeam (757) | 5 - 6 | 3 | 1-2-61 | 4- 7-61 | 1257 | 52 | 3.06 |
| Carrie (797) | 4 - 5 | 2 | 12-15-60 | - - - | 1242 | 43 | 3.05 |
| <u>Group 2 (Holsteins)</u> | | | | | | | |
| Fay (645) | 8 - 10 | 5 | 11-18-60 | 2-21-61 | 1252 | 47 | 3.12 |
| Julia (658) | 8 - 4 | 6 | 9- 8-60 | 2-14-61 | 1414 | 30 | 3.09 |
| Trixie (704) | 7 - 7 | 4 | 10-15-60 | 2- 4-61 | 1250 | 43 | 3.90 |
| <u>Group 3 (Jerseys)</u> | | | | | | | |
| Molly (453) | 5 - 5 | 3 | 1-20-61 | 2-26-61 | 846 | 23 | 4.43 |
| Juliette (397) | 7 - 4 | 4 | 1- 4-61 | 2-27-61 | 863 | 24 | 4.52 |
| Vanity (378) | 7 - 11 | 5 | 11- 7-60 | 3- 3-61 | 841 | 19 | 4.70 |

APPENDIX B

PROXIMATE ANALYSES OF THE CONCENTRATES AND HAY FED DURING THE EXPERIMENT

| | Dry Matter | Protein | Fat | Crude fiber | Nitrogen- free extract | Ash |
|--------------|---------------|---------|------|----------------|------------------------------|------|
| | (Per cent) | | | | | |
| Concentrates | 88.60 | 22.30 | 3.12 | 4.50 | 59.96 | 5.72 |
| Hay | 89.65 | 16.70 | 1.80 | 25.70 | 36.28 | 9.17 |

APPENDIX C

ANALYSIS OF VARIANCE OF THE POUNDS OF $\frac{1}{4}$ PER CENT
FCM PRODUCED BY 9 COWS FED A NO GRAIN, NORMAL
AND HIGH GRAIN RATION FOR $\frac{1}{4}$ WEEKS

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|------------------------|--------------------------|-------------------|----------------|------------|
| Total | 26 | 1,819,832 | | |
| Between treatments | 2 | 40,988 | 20,494 | 8.8** |
| Between squares | 2 | 1,291,229 | 645,615 | 276.7** |
| Between periods | 6 | 192,545 | 32,091 | 13.8** |
| Between cows | 6 | 271,739 | 45,290 | 19.4** |
| Error | 10 | 23,331 | 2,333 | |

**Significant at the 1 per cent level.

APPENDIX D

ANALYSIS OF VARIANCE OF THE POUNDS OF SNF PRODUCED
 BY 9 COWS FED A NO GRAIN, NORMAL AND
 HIGH GRAIN RATION FOR 4 WEEKS

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---------------------------|--------------------------|----------------------|----------------|------------|
| Total | 26 | 16,862 | | |
| Between treatments | 2 | 567 | 284 | 12.8** |
| Between squares | 2 | 12,408 | 6,204 | 279.4** |
| Between periods | 6 | 1,380 | 690 | 31.1** |
| Between cows | 6 | 2,285 | 1,143 | 51.5** |
| Error | 10 | 222 | 22.2 | |

**Significant at the 1 per cent level.

APPENDIX E

ANALYSIS OF VARIANCE OF THE POUNDS OF PROTEIN
PRODUCED BY 9 COWS FED A NO GRAIN,
NORMAL AND HIGH GRAIN RATION
FOR 4 WEEKS

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---------------------------|--------------------------|----------------------|----------------|------------|
| Total | 26 | 2,009 | | |
| Between treatments | 2 | 126 | 63 | 26.3** |
| Between squares | 2 | 1,325 | 663 | 276.3** |
| Between periods | 6 | 160 | 27 | 11.3** |
| Between cows | 6 | 374 | 62 | 25.8** |
| Error | 10 | 24 | 2.4 | |

**Significant at the 1 per cent level.